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Profit-enhancing know-how disclosure: A strategic view*

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Abstract

In general, the disclosure of know-how and technological knowledge could harm the disclosing firm. Firms, however, often share their know-how freely and enhances their profits. We provide a theoretical framework and a new insight for know-how disclosure. We consider a multi-product oligopolistic market. An incumbent firm that can disclose its cost-reducing know-how and several new entrants exist. Each firm supplies products in two separate markets. The incumbent firm has already allocated its production resources to one of the markets (market A) and discloses its know-how concerning production in market A. We show that the disclosure of know-how for cost reduction can enhance the profit of the incumbent (the disclosing) firm. Using the disclosed know-how, the entrants can produce at a low cost at market A and allocate their production resources to the other market. As a result, the competition at market A is milder than that in the case in which the incumbent does not disclose its know-how. Moreover, the disclosure could harm the new entrants. The result implies that the incumbent firm may disclose its know-how in its industry as a payoff-enhancing entry deterrent.

JEL classification codes: L13, M21, D21

Key words: know-how, disclosure, resource allocation, multi-product firms

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1 Introduction

Disclosure of know-how and technological knowledge is beneficial from the viewpoint of social welfare. Such behavior, however, could rebound on the disclosing firm. To encourage the disclosure of know-how or knowledge, in many countries, governments ensure exclusive rights of innovators by patent laws, and innovators can license their know-how or technological knowledge for firms and institutes. In the literature of know-how disclosure, therefore, the following two topics are eagerly discussed: (1) how to licence (see Kamien and Tauman (1984, 1986), Katz and Shapiro (1985, 1986), and Muto (1993), among others) and (2) how to protect innovators (see Gilbert and Shapiro (1990), Klemperer (1990), and other special issues of the *RAND Journal of Economics* (see Saloner (1990)) as well as Scotchmer (2004)).

On the other hand, some researchers point out that, oftentimes, innovating firms do not sell or license their innovation, but, instead, they freely reveal the details of their innovation. For instance, von Hippel (1988) pointed out that rival firms routinely exchanged technical information in the steel mini-mill industry and proposes a theory of know-how sharing based on the idea that it reduces cost (see also von Hippel and Schrader (1996)). Eaton and Eswaran (2001) build a model based on the idea of von Hippel (1988).

In the literature of economics, some researchers discuss the profitability of freely revealing knowledge. In his examination of the history of technical advances in England's Cleveland district during the nineteenth century, Allen (1983, pp.18-20) provides three possibilities in which the revelation of technical information might have been profitable: (a) If the production process involves a natural resource which commands a rent and if the invention lowers the costs of firms' processing only that portion of the resource with certain characteristics, then the owners of those firms might benefit from releasing technical information; (b) If the world is characterized by competition among firms in different regions with different relative factor prices, each region can lower its costs and raise its resource rents relative to other regions by practicing collective invention and broadcasting technical information; and (c) Output and profits would be greater if the existing regime of trade secrets was replaced by a new regime of free information exchange. Based on the third possibility listed by Allen (1983), Cowan and Jonard (2003) developed a formal model that account for the dynamics of knowledge and collective invention and demonstrated that a communication network structure has a strong influence on system performance. De Fraja (1993) considers an R&D tournament in which two firms invest until an innovation occurs. In his model, when the payoff of the loser is close to that of the winner, the firms disclose their knowledge concerning R&D investments because the disclosure shortens the expected time of the R&D competition and economizes on the investment costs.

Free revelation of knowledge and know-how is especially observed in the information technology industry. Freeware is a typical example. Independent programmers develop applications, such as text editing, graphics, and music, and they freely disclose the applications. A typical explanations for this is that, in this manner, such programmers publicize their skills and abilities to their communities and computer firms (see Raymond (1999) and Lerner and Tirole (2002)). Open-source programs are also related to the free revelation of innovation. In the information technology industry, commercial firms support open-source programming. Some explanations are as follows: the program is a complement to the commercial firm's product, and helping the programm damages the rival of the helping firm (see Kende (1998)). As pointed out by Mustonen (2005), some firms create competition by supporting open-source communities, in which programs are substituted for another firm's programs. Based on the idea of Lerner and Tirole (2002), Mustonen (2005) developed an analytical model in which a copyright firm and a copyleft (open-source) community compete in a program market and showed that the copyright firm makes its program compatible with that of the copyleft community and supports the copyleft community if the network effect of the program is weak.

We can summarize the positive effects of knowledge disclosure in the literature: 1. Give and take (von Hippel (1988) and Eaton and Eswaran (2001)); 2. Input sector (Allen (1983)); 3. Interregional trade (Allen (1983)); 4. Information exchange (Allen (1983) and Cowan and Jonard (2003)); 5. Saving R&D expenditure (De Fraja (1993)); 6. Signaling (Reymond (1999)); 7. Complementarity (Kende (1998)); and 8. Network externality (Mustonen (2005)). In this paper, we provide a new insight concerning knowledge disclosure. We focus on resource allocation strategies that have not been considered in the literature.

In this paper, we provide a theoretical framework to show a new insight for know-how disclosure.

We consider a multi-product oligopolistic market. An incumbent firm that can disclose its cost-reducing know-how and several new entrants exist. Each firm supplies its products in two separate markets, A and B. Each multi-product firm has to allocate its production resource for the markets. If a firm allocates its resource for market A, it can produce a lower marginal cost in market A, but it has to incur a higher marginal cost in market B.[1] The incumbent firm has already allocated its resources to market A and discloses its know-how concerning production at market A. By the disclosure, the entrants can economize on their production in market A. In our paper, we assume that the disclosed know-how is more effective for an entrant that allocates its resources to market B (called type B) than for one that allocates its resources to market A (called type A). In the literature of R&D, as the efficiency of a product improves, the marginal effect of cost-reducing activities decreases. We now apply these steps to our settings. At market A, type A is more efficient than type B. Therefore, the benefit of the know-how disclosure for type A is smaller than that for type B.[2]

Those resource allocations are commonly observed in many industries. In the automobile industry, the "market", for example, represents car size for instance, and a resource allocation by a firm, for example, indicates that the firm produces small cars efficiently and large cars inefficiently. In the consumer electronics industry, possible interpretations of the "market" include televisions, refrigerators, and electronic ovens, and a resource allocation by a firm could be interpreted as its ability to produce televisions efficiently while it is unable to produce electronic ovens efficiently.

From the model, we show that the disclosure of know-how for cost reduction can enhance the profit of the incumbent (the disclosing) firm. That is, it is possibility that revealing technical information could be profitable. We now show the intuition behind the result. First, suppose that the incumbent does not disclose its know-how. In this case, some entrants allocate their resources for market A, and some other entrants allocate their resources for market B. The number of firms that allocate their resources to market A is nearly equal to that of firms that allocate their resources to market B. Now, suppose that the incumbent discloses its know-how. Using the

[1] This setting is somewhat similar to the spatial discrimination model, in which firms choose their locations. Concerning the spatial discrimination model, see Hamilton *et al.* (1989), Anderson and Neven (1991), Pal (1998), and Matsushima (2001), among others.

[2] To clarify the analysis, we assume that the benefit of know-how disclosure for type A is sufficiently small. In the latter part of the Introduction, we provide the intuition behind the result based on the assumption.

disclosed know-how, each entrant can produce its product at a low marginal cost at market A. Allocating their resources for market A is ineffective for the entrants. Know-how disclosure induces some entrants to change the allocation patterns of their resources. The change in the allocation patterns mitigates the competition at market A because the number of tough competitors at market A (firms allocating their resources to market A) decreases by know-how disclosure. The decrease in the number is beneficial for the incumbent firm. Of course, know-how disclosure reduces the production costs of entrants in market A who allocate their resources to market B. This is harmful for the incumbent firm. These are trade-offs. In our model, if the incumbent firm sets the degree of know-how disclosure appropriately, the former positive effect dominates the latter negative one. Therefore, revealing technical information could have been profitable.

In the model, know-how disclosure can harm entrants who allocate their resources to market B. As mentioned earlier, know-how disclosure reduces the production costs of entrants in market A who allocate their resources to market B. This is beneficial for the entrants. On the other hand, know-how disclosure induces some entrants to change the allocation patterns of their resources. It enhances the competition at market B because the number of tough competitors at market B (firms allocating their resources to market B) increases by know-how disclosure. These are trade-offs. In this sense, the profits of the entrants who allocate their resources to market B are seen as the flip side of the profit of the incumbent. The result implies that the incumbent firm may disclose its know-how in its industry as a payoff-enhancing entry deterrent.

The paper proceeds as follows. The next section provides the case of a Japanese supermarket chain. Section 3 outlines the basic model. Section 4 provides the results. Finally, section 5 offers some concluding remarks.

2 The case of a Japanese supermarket chain

2.1 Background

In general, a firm would never take actions to disclose its know-how. However, there are firms who act in a manner which is different from this common belief. For example, it is known that Kansai Supermarket (hereinafter referred to as KSP), a regional supermarket chain in Japan, actively disclosed its own know-how to potential rivals between 1970 and 1985, which was a growth period for the supermarket industry in Japan.

KSP, a regional chain, was established in 1959. As the "Kansai" in its name indicates, KSP is a retailer with stores only in the Kansai region such as in Osaka and Hyogo. In March of fiscal 2004, the firm had gross sales of approximately 102 billion yen, with a total of 51 stores.

It has been widely acknowledged by the industry and academic societies that KSP was a pioneer in Japan in the establishment of the supermarket business (Ishihara (1998)). Until KSP began to innovate, it was believed that the job of controlling the freshness of such perishable foods as vegetables and fish could only be performed by specialized craftsmen. In the 1970s KSP analyzed the tacit knowledge possessed by craftsmen, broke down that knowledge, standardized it and put it into a manual. As a result, it became possible for KSP to realize a sales space where even part-time workers, at low labor costs, could maintain freshness at the same level as that achieved by craftsmen. It has been recognized in the industry that these activities of KSP were revolutionary, clarified by the fact that 91 articles about the activities of KSP appeared in the same monthly trade journal *Hanbai Kakushin*, which means Revolution in Retailing in Japanese, between 1971 and 1984.

2.2 Know-how disclosure

The period from 1970 to 1985, when KSP was actively innovative, was the time that the supermarket industry was established in Japan, and it was also a period of growth for the industry. Figure 1 shows the fluctuations in the number of stores and gross sales amounts from 1975 to 1985 for Maruetsu and Life (both major supermarket chains), Okuwa (which is about the same scale as KSP) and KSP.

[Figure 1 about here]

The gross sales per store are the only data available by which to compare the business results for the stores at the time - and in comparing these data we have found from Figure 2 that KSP's business results surpassed those of other firms.

[Figure 2 about here]

What we would like to draw attention to here is the fact that KSP, a supermarket chain which had developed cutting-edge know-how, actively disclosed its know-how to other firms in the same industry, including its rivals. Rather than limiting itself to disclosing know-how through the above-mentioned magazine articles, the firm actively disclosed know-how through the activities of a business exchange group. It has been reported that a maximum of 77 supermarket firms participated in this group to absorb the know-how of KSP (Mizuno (2005)).

This case example is very interesting for a number of reasons. First is the fact that the know-how which KSP disclosed was at the cutting edge in the industry at the time. Second is the timing by which KSP disclosed its know-how at the same time that this know-how was developed. Third is the fact that among the firms to whom KSP disclosed its know-how were rival supermarkets who had stores in the same geographical area as KSP. And finally is the fact that those firms spared no effort to obtain the know-how in question. Innovation-related information such as know-how is sometimes difficult to transfer (von Hippel (1994) and Ogawa (1998)). Thus, KSP not only allowed those firms to observe its stores and lend them manuals, but also sometimes even dispatched its own employees to instruct employees of the other firms, and brought employees from the other firms into its own stores for a number of years in order to transmit know-how to them.

It would be difficult to understand the above-mentioned actions of KSP from the viewpoint that know-how which is unique to one's own firm should be protected. However, that is only if one assumes that the firm in question is a single-product firm which only handles one product. The moment one assumes that the firm in question handles two or more products, it becomes possible for that firm to create a favorable situation for itself by disclosing its know-how to its rivals.

The KSP case presented here is not categorized into the patterns concerning the positive effects of know-how disclosure (see Section 1). In the case of KSP, reciprocities of know-how among firms do not exist (cases 1 and 4); KSP does not have input sectors or upstream firms (case 2); the competition among KSP and the other retailers holds in a region (case 3); and the production complementarity or network externality among KSP and other retailers does not exist (cases 7 and 8). From the discussion above, we cannot say that the effects of cost saving or signaling do not exist (cases 5 and 6). The matter is discussed in Section 5.

2.3 Fact

As mentioned above, the following is clarified by the analysis in this paper. That is to say that, assuming that a firm handles more than one product, it may be possible for that firm to create a competitive advantage for itself by disclosing know-how to its rivals. If a firm discloses to a rival know-how regarding a certain product, that means that the rival to whom the disclosure is made will be in possession of know-how about the product in question - and so it will think it reasonable to allocate management resources into another product. As a result, the firm to whom the disclosure has been made will no longer sink management resources into the same product field as the firm that has disclosed know-how, enabling the discloser to maintain its competitive advantage.

The analysis findings given above have also been observed in the case example of KSP, to which attention has been drawn by this paper. It has been reported that some of the rival firms to whom know-how on the management of perishable foods was disclosed by KSP, took action to differentiate themselves by selecting goods, including deluxe imported goods and prepared food, among others (Ogawa, August 1, 2005; interviews with president of KSP).

3 The model

There are four multi-product firms.[3] Firm 0 is the incumbent firm and firms 1, 2, and 3 are entrants. Each firm supplies its products in two separated markets, A and B. Market i is the one for product i ($i = A, B$). Let p_i denote the price of the production in market i ($i = A, B$) and q_i, its quantity in market i. The demand functions at markets A and B for the products are represented by $q_A = 1 - p_A$ and $q_B = 1 - p_B$, respectively. In each market, the firms compete in quantity.

Each multi-product firm supplies its products for the markets. Each of them has to locate at one of the markets. The incumbent can produce its product without costs at the market in which it locates, while it has to incur a constant marginal cost t to produce its product at the other market. Each entrant incurs a constant marginal cost $c(> 0)$ at the market in which it locates, while it has to incur a constant marginal cost $c + t$ to produce its product at the other market. That is, the entrants are less efficient than the incumbent. To assure positive quantities supplied by each firm, we assume that $t < (1 - 2c)/4$. We can interpret "market" as varieties of goods and the point of a

[3] The qualitative property of our results does not depend on the number of multi-product firms. All proofs for the case of n firms are available upon request.

firm's location as the firm's most efficient sector.[4] For example, in the automobile industry, "space" represents car size, and a firm's location indicates that the firm produces small cars efficiently but large cars inefficiently. In the consumer electronics industry, possible interpretations of "space" include televisions, refrigerators, and electric ovens, and a firm's location could be interpreted as its ability to produce televisions efficiently and its inability to produce electronic ovens efficiently.[5]

Firm 0 has already located at A, that is, it has already allocated its resources to product A. The other firms decide where to locate. Before they choose their locations, firm 0 decides whether to disclose its know-how concerning product A. If it discloses its know-how, a firm locating at B can produce product A with a constant marginal cost $c+t-e$ (e is a positive constant), and a firm locating at A can produce product A with a constant marginal cost $c-f$ (f ($< e$) is a positive constant). That is, know-how disclosure by firm 0 reduces the marginal costs of the rivals. The disclosure helps entrants making units of product A.

We think that the assumption, $f < e$, is plausible. In the literature of R&D, as the efficiency of product improves, the marginal effect of cost-reducing activities decreases. We now imply it to our setting. At market A, a firm that allocates its resource to market A (type A) is more efficient than that which allocates its resources to market B (type B). Therefore, the benefit of the disclosure for type A (the value of f) is smaller than that for type B (the value of e), that is, $f < e$.

[Table 1 about here]

To simplify the analysis, we assume that $c = f = 0$.[6] The assumption means that the disclosure is not useful for a firm allocating its resources to product A. We think that the assumption is plausible because firms cannot produce units of product A more efficiently than the incumbent firm (firm 0) that discloses its know-how and leads the production technology at market A.[7] Controlling the

[4] In a spatial price discrimination model, Matsushima and Matsumura (2003) use the interpretation. We can also interpret the marginal cost t as a transport cost to supply the market in which it does not locate.

[5] This interpretation is similar to those of Eaton and Schmitt (1994) and Norman and Thisse (1999). To explain flexible manufacturing systems (FMS), they use spatial price discrimination models.

[6] The assumption that $f = 0$ is essential to derive the main result. Even though an entrant which allocate its resources to market A is more efficient than the incumbent ($f > 0$), our result holds when the difference between the efficiencies of the incumbent and the entrant is small enough (f is small enough). We can show the result of the non-simplified version.

[7] As discussed in von Hippel (1994) and Ogawa (1998), innovation-related information, such as know-how, is sometimes difficult to transfer. Therefore, we think that it is difficult for entrants to be more efficient than the

amount of information concerning the product which is efficiently produced by firm 0, firm 0 is able to control the level of e. The cost structures of the model are summarized as follows.

[Table 2 about here]

The game runs as follows. In the first stage, firm 0 decides whether it discloses its know-how concerning product A. If it decides to disclose, it sets the level of e. In the second stage, given the decision of firm 0, firms 1, 2, and 3 decide where to locate. In the third stage, given the locations of the firms, each firm decides its quantities supplied at the markets.

4 Result

We now show the main results of the paper. Before we discuss the main concern, we show the result of n-firm quantity (Cournot) competition.[8] Let c_i ($i = 1, \dots, n$) be the constant marginal cost of firm i. When the (inverse) demand function is $p = 1 - Q$ (p: price; Q: the aggregate industry output), the profit of firm i (π_i), Q, and consumer surplus (CS) are

$$\pi_i = \frac{(1 + \sum_{j=1}^{n} c_j - (n+1)c_i)^2}{(n+1)^2}, \; Q = \frac{n - \sum_{j=1}^{n} c_j}{n+1}, \; CS = \frac{(n - \sum_{j=1}^{n} c_j)^2}{2(n+1)^2}. \tag{1}$$

In the following two subsections, we consider two cases: (1) firm 0 does not disclose its know-how; and (2) firm 0 discloses its know-how. We now discuss the locations of firms.

4.1 Non disclosure of know-how

Suppose that $4 - k$ firms locate at A and k firms locate at B ($k = 0, 1, 2, 3$). The profit of the firm locating at A (denoted as $\pi_A(k)$) and that of the firm locating at B (denote it as $\pi_B(k)$) are

$$\begin{aligned} \pi_A(k) &= \frac{(1 + ((4-k) \times 0 + kt) - (4+1) \times 0)^2}{(4+1)^2} + \frac{(1 + ((4-k)t + k \times 0) - (4+1)t)^2}{(4+1)^2} \\ &= \frac{2 - 2t + (1 + 2k + 2k^2)t^2}{25}, \end{aligned} \tag{2}$$

$$\begin{aligned} \pi_B(k) &= \frac{(1 + ((4-k) \times 0 + kt) - (4+1)t)^2}{(4+1)^2} + \frac{(1 + ((4-k)t + k \times 0) - (4+1) \times 0)^2}{(4+1)^2} \\ &= \frac{2 - 2t + (41 - 18k + 2k^2)t^2}{25}. \end{aligned} \tag{3}$$

incumbent.

[8] The way to derive the result is mentioned in Shy (1995, pp.126-7).

If $\pi_A(k) > \pi_B(k+1)$, the firms locating at A do not have an incentive to move to B. If $\pi_B(k) > \pi_A(k-1)$, the firms locating at B do not have an incentive to move to A. Therefore, if the inequalities hold, the location pattern in which k firms locate at B is an equilibrium outcome. We have the following lemma:

Lemma 1 *The following location pattern is a unique equilibrium outcome: 2 firms (including firm 0) locate at A, and 2 firms locate at B. Under the location pattern, each firm's profit is*

$$\pi_A(2) = \pi_B(2) = \frac{2 - 2t + 13t^2}{25}. \tag{4}$$

The location pattern is quite natural. As the number of firms at a location (market) increases, the intensity of competition at that market is enhanced. The intensity of competition at the other market diminishes. If the number of firms at the first market is larger than that at the other market, to avoid tough competition at the first market, some of the firms move to the other market, which has a smaller number of firms. In equilibrium, each market has the same number of firms.

From (1), consumer surplus (denote as CS_n) is

$$CS_n = 2 \times \frac{(4-2t)^2}{2(4+1)^2} = \frac{4(2-t)^2}{25}. \tag{5}$$

From (4) and (5), social welfare (denote as SW_n) is

$$SW_n = CS_n + 2\pi_A(2) + 2\pi_B(2) = \frac{8(3 - 3t + 7t^2)}{25}. \tag{6}$$

4.2 Disclosure of know-how

Suppose that $4-k$ firms locate at A and k firms locate at B ($k = 0, 1, 2, 3$). The profit of the firm locating at A (denote it as $\pi_A^d(k)$) and the profit of the firm locating at B (denote it as $\pi_B^d(k)$) are

$$\begin{aligned}
\pi_A^d(k) &= \frac{(1 + ((4-k)\times 0 + k(t-e)) - (4+1)\times 0)^2}{(4+1)^2} + \frac{(1 + ((4-k)t + k\times 0) - (4+1)t)^2}{(4+1)^2} \\
&= \frac{2 - 2t + (1 + 2k + 2k^2)t^2}{25} - \frac{ek(2 + (2t-e)k)}{25}, \qquad (7) \\
\pi_B^d(k) &= \frac{(1 + ((4-k)\times 0 + k(t-e)) - (4+1)(t-e))^2}{(4+1)^2} + \frac{(1 + ((4-k)t + k\times 0) - (4+1)\times 0)^2}{(4+1)^2} \\
&= \frac{2 - 2t + (41 - 18k + 2k^2)t^2}{25} + \frac{e(5-k)(2 - (2t-e)(5-k))}{25}. \qquad (8)
\end{aligned}$$

If $\pi_A^d(k) > \pi_B^d(k+1)$, the firms locating at A do not have an incentive to move to B. If $\pi_B^d(k) > \pi_A^d(k-1)$, the firms locating at B do not have an incentive to move to A. Therefore, if the inequalities hold, the location pattern in which k firms locate at B is an equilibrium outcome. We have the following lemma:

Lemma 2 *Suppose that e satisfies the following inequalities:*

$$t^2 < e. \tag{9}$$

The following location pattern is the unique equilibrium outcome: firm 0 locates at A and the other 3 firms locate at B. Under the location pattern, each firm's profit is

$$\pi_A^d(3) = \frac{2 - 6e + 9e^2 - 2(1 + 9e)t + 25t^2}{25}, \tag{10}$$

$$\pi_B^d(3) = \frac{2(1 + 2e + 2e^2) - 2(1 + 4e)t + 5t^2}{25}. \tag{11}$$

On the range described in (9), the supreme of $\pi_A^d(3)$ is

$$\frac{(2 - 2t + t^2)(1 + 9t^2)}{25}, \tag{12}$$

which is achieved when e converges to t^2.

As shown in Table 2, locating at B is cost-advantageous for firms. Firms locating at B are able to supply products to market A at a low marginal cost $(t - e)$, but firms locating at A have to incur the higher marginal cost t to supply product to market B. As the value of e increases, the cost advantage is more significant. Given a location pattern in which the number of firms is the same at both markets, as the value of e increases, to get the cost advantage, some of the firms that would locate at A move from A to B. Therefore, under the level of e in (9), a firm changes its location from A to B.

From (1), consumer surplus (denote as CS_d) is

$$CS_d = \frac{(4 - 3(t - e))^2}{2(4 + 1)^2} + \frac{(4 - t)^2}{2(4 + 1)^2} = \frac{32 + 24e + 9e^2 - 2(9e + 16)t + 10t^2}{50}. \tag{13}$$

From (10), (11), and (13), social welfare (denote as SW_d) is

$$SW_d = CS_d + \pi_A^d(3) + 3\pi_B^d(3) = \frac{3(16 + 12e + 17e^2 - 2(8 + 17e)t + 30t^2)}{50}. \tag{14}$$

4.3 The incumbent firm

In this subsection, we assume that e satisfies the inequalities in (9). The discussion turns now to the difference in firm 0's profit when it discloses its know-how and when it does not. From (4) and

(10), the difference is as follows:

$$\pi_A^d(3) - \pi_A(2) = \frac{3(4t^2 - 2(1+3t)e + 3e^2)}{25}. \tag{15}$$

If this is positive, that is, $\pi_A^d(3) - \pi_A(2) > 0$, the disclosure of its know-how is beneficial for firm 0. From (9) and (15), we have the following proposition:

Proposition 1 *Disclosing its know-how enhances the profit of firm* 0*, if and only if it sets the level of* e *as follows:*

$$t^2 < e < \frac{1 + 3t - \sqrt{1 + 6t - 3t^2}}{3}. \tag{16}$$

[Figure 3 about here]

As the value of e increases, the cost advantage of firms locating at B is enhanced. In other words, the disadvantage of the firm disclosing its know-how is enhanced by the increment in the level of e. Based on the property, someone may think that such know-how disclosure is obviously harmful for the disclosing firm. In our model, however, another viewpoint has been provided.

The viewpoint is that know-how disclosure induces some firms to change their plans of location (”specialized” product). As mentioned in Lemma 2, these firms change their specialized product from product A to product B. The change mitigates the competition at market A and is beneficial for the firm disclosing its know-how. The viewpoint is not discussed in the literature of know-how disclosure, thus constituting a new insight into the issue.

Know-how disclosure has the positive and negative effects reported above. When the firm disclosing its know-how sets an appropriate level of e (the level induces a firm to change its location but is not too large), the positive effect dominates the negative one. As a result, know-how disclosure which reduces the costs of its rivals, really increases its own profit.

4.4 Entrants

In this subsection, we consider the entry deterrent effects of know-how disclosure. As mentioned in Section 4.2, know-how disclosure enhances the efficiencies of the rival firms. As first glance, it would increase the profits of the rivals. In the model, however, the converse holds.

In each case, the firms earn the same profit levels (see the discussion in Sections 4.1 and 4.2 and equations in (4) and (11)). We now calculate the difference between the profit in which firm 0 discloses its know-how and that in which it does not. From (4) and (11), we have the difference:

$$\pi_B^d(3) - \pi_B(2) = \frac{4(e^2 + (1-2t)e - 2t^2)}{25} < 0, \text{ for any } e \text{ in (16).} \tag{17}$$

From the inequality, we have the following proposition:

Proposition 2 *Suppose that firm* 0 *sets the level of* e *within the range in (16). Disclosing the know-how of firm* 0 *decreases the profits of the other three firms.*

By the disclosure, a firm that would locate at A moves to B. This enhances the competition at market B. If the level of e were large enough, the transport cost reduction (positive) effect of the disclosure would dominate the negative effect of the competition. In this case, however, the disclosing firm sets the level of e at an intermediate level (see (16)). Therefore, the enhanced competition harms the other three firms. In this sense, the profits of the entrants that allocate their resources to market B can be seen as the flip side of the profit of the incumbent. The result implies that the incumbent firm may disclose its know-how in its industry as a payoff-enhancing entry deterrent.

4.5 Welfare

We now discuss the welfare implications of know-how disclosure.

The first implication if know-how disclosure is the difference between the consumer surplus when firm 0 discloses its know-how and when it does not. From (5) and (13), we have the difference:

$$CS_d - CS_n = \frac{2t^2 + 6(4-3t)e + 9e^2}{50} > 0, \text{ for any } t < 1/4. \tag{18}$$

From the inequality, we have the following proposition:

Proposition 3 *Disclosing the know-how of firm* 0 *enhances consumer surplus.*

Suppose that a fixed amount of the product exists in the markets. Equal allocation of the product to markets A and B is the worst way from the viewpoint of consumer surplus because consumer surplus is convex with respect to the quantity supplied. An asymmetric allocation of the product occurs by the relocation induced by the disclosure. The asymmetric allocation increases consumer surplus.

[Figure 4 about here]

The second implication is the difference between social welfare when firm 0 discloses its know-how and when it does not. From (6) and (14), we have the difference:

$$SW_d - SW_n = \frac{51e^2 + 6(6-17t)e - 22t^2}{50}. \tag{19}$$

From the equation, we have the following proposition:

Proposition 4 *Suppose that firm* 0 *sets the level of* e *within the range in (16). Disclosing the know-how of firm* 0 *enhances social welfare if and only if*

$$\begin{cases} t \in \left(0, \dfrac{51-\sqrt{1887}}{51}\right), & \textit{for any } e, \\ t \in \left[\dfrac{51-\sqrt{1887}}{51}, \dfrac{21-\sqrt{231}}{27}\right), & e \geq \dfrac{\sqrt{3(108-612t+1241t^2)}-3(6-17t)t}{51} \equiv \bar{e}, \end{cases} \tag{20}$$

otherwise, it diminishes social welfare.

From the viewpoint of social welfare, know-how disclosure has two effects. One is an efficiency-enhancing effect, and the other is a location-distorting effect. The former is positive and the latter is negative. The positive effect is enhanced by the increment in the level of e because the efficiency of firms locating at B improves. The negative effect stems from the reduced competitiveness, which is induced by the asymmetric location pattern, at market A. As the level of t increases, the competition at A is weakened because the entrants locating at B becomes less aggressive at A. Therefore, Proposition 4 holds.

5 Concluding remarks

We examined the positive effects of a firm's disclosing its know-how to rival firms. In general, firms do not disclose to rival firms know-how that would give these rival firms a competitive advantage. This is because, once a firm has disclosed its know-how, the rival firm will probably use that information to try to diminish the competitive advantage of the discloser. As a result, the firm which has disclosed the information might lose its competitive advantage. This is why it is generally assumed that a firm should never disclose its know-how.

However, there was a regional retail-chain which acted in a manner which is different from this common belief. KSP was an innovator in supermarket operations and actively disclosed its own know-how to existing and potential rivals between 1970 and 1985, which was a growth period for the supermarket industry in Japan.

On the basis of this observation, we provided a theoretical framework to explain such know-how disclosure to rivals. We showed that a firm could create a competitive advantage for itself by disclosing its know-how to its rivals if we assume that a firm handles more than one product. If a firm discloses to a rival its know-how regarding a certain product, the rival to whom the disclosure is made will be in possession of the know-how about the product in question; thus it would be reasonable for the rival to allocate management resources into another product. As a result, the rival will no longer allocate management resources into the same product field as the discloser, and the discloser will be able to maintain its competitive advantage.

The case of KSP provides a good example. Some of the rival firms to whom know-how on the management of perishable foods was disclosed by KSP, took action to differentiate themselves from KSP by selecting goods, including deluxe imported goods and prepared food, among others. As a consequence, KSP maintained its competitive advantage.

An implication of this study is that a multi-product firm could gain a competitive advantage from know-how disclosure when the product markets of the firm are growing. Particularly, this strategy could be attractive to mass merchandisers such as Wal-Mart because such retailers generally handle two or more product categories and always search for new promising product categories. For example, in the growing Electric Commerce market, amazon.com might be able to maintained its competitive advantage if it discloses its know-how in book inventory management to rival firms.

We believe that our model could be applicable not only to retailing but also to multi-product manufacturers. For instance, in the digital home appliance market, such as DVDs or cameras, it might be a good strategy for Panasonic to disclose its know-how in DVD production to Samsung and Haier Electronics Group to maintain its global market leadership. In this respect, the applicability and generalizability of our model will need to be explored.

As discussed by many researchers, know-how disclosure has several effects on the disclosing firms or persons. In this paper, we discussed the effect on the resource allocation strategies of firms. In the case of KSP, as discussed by Reymond (1999), signaling effects might be important. By disclosing its know-how, KSP might intend to appeal to upstream firms and rivals for its cost efficiency. First, we mentioned the effect of know-how disclosure on upstream firms. KSP buys many goods from upstream firms and sells the goods to consumers. As discussed in the literature of industrial organization, wholesale prices set by upstream firms decrease as the efficiency of the downstream firm is improved. Therefore, appealing its efficiency by the know-how disclosure would be effective for KSP. As reported by Mizuno and Ogawa (2004), know-how disclosure by KSP reduces wholesale prices. Providing a model to explain this effect is a considerable future research. Second, we mentioned the effect of know-how disclosure on rivals. If rivals recognize KSP's cost efficiency on a particular product, they will tend to avoid allocating their resources to that particular product because they will realize that it is difficult to make a profit from that particular product. The effect on the rivals will strengthen our main results.

[2005.11.1 732]

Appendix

Proof of Lemma 1 To show the lemma, we solve the following inequalities:

$$\pi_A(k) > \pi_B(k+1), \quad \pi_B(k) > \pi_A(k-1).$$

Solving the inequalities, we have

$$\pi_A(k) - \pi_B(k+1) = \frac{8(2k-3)t^2}{25} > 0, \quad \Rightarrow \quad k > \frac{3}{2}, \tag{21}$$

$$\pi_B(k) - \pi_A(k-1) = \frac{8(5-2k)t^2}{25} > 0, \quad \Rightarrow \quad k < \frac{5}{2}. \tag{22}$$

The integer of k which satisfies both inequalities in (21) and (22) is 2. Therefore, Lemma 1 holds. Q.E.D.

Proof of Lemma 2 To show the lemma, we solve the following inequality:

$$\pi_B^d(k) > \pi_A^d(k-1).$$

To consider the location choices of firms, suppose that $k-1$ firms locate at B and $5-k$ firms locate at A ($k = 1, 2, 3$). In the case, the profit of the firm which locates at A is $\pi_A^d(k-1)$. If one of the firms locating at A changes its location, the number of firms which locate at B is k, and the profit of the relocating firm is then $\pi_B^d(k)$. Therefore, if the inequality holds for any k ($k = 1, 2, 3$), in any case, the entrants do not locate at A, that is, 3 firms locate at B in equilibrium. Solving the inequality, we have

$$\pi_B^d(k) - \pi_A^d(k-1) = \frac{4[e(2+e-2t) + 5(e^2 - 2et + 2t^2) - 2k(e^2 - 2et + 2t^2)]}{25} > 0,$$

$$\Rightarrow \quad k < \frac{5}{2} + H, \quad \left(H \equiv \frac{e(2+e-2t)}{2(e^2 - 2et + 2t^2)} \right). \tag{23}$$

When e satisfies the inequalities in (9), H satisfies $1/2 < H$. The integers of k which satisfy the inequality in (23) are 1, 2, and 3. Therefore, Lemma 2 holds. Q.E.D.

Proof of Proposition 1 $\pi_A^d(3) - \pi_A(2)$ in (15) is positive if and only if

$$e < \frac{1 + 3t - \sqrt{1 + 6t - 3t^2}}{3}.$$

The right-hand side of the inequality is larger than t^2 in (9). Therefore, Proposition 1 holds. Q.E.D.

Proof of Proposition 2 $\pi_B^d(3) - \pi_B(2)$ in (17) is increasing in e. Substituting $e = (1 + 3t - \sqrt{1 + 6t - 3t^2})/3$ into $\pi_B^d(3) - \pi_B(2)$ in (17), we have:

$$-\frac{4\left(\sqrt{1+6t-3t^2} - (1+3t-6t^2)\right)}{45}.$$

This is negative because $(\sqrt{1+6t-3t^2})^2 - (1+3t-6t^2)^2 = 36(1-t)t^2 > 0$. Q.E.D.

Proof of Proposition 4 $SW_d - SW_n$ in (19) is increasing in e. Substituting $e = t^2$ and $e = (1 + 3t - \sqrt{1 + 6t - 3t^2})/3$ into $SW_d - SW_n$ in (19), we have

$$\frac{t^2(14 - 102t + 51t^2)}{50}, \quad (e = t^2)$$
$$\frac{(7 + 21 - 27t^2) - 7\sqrt{1 + 6t - 3t^2}}{15}, \quad (e = (1 + 3t - \sqrt{1 + 6t - 3t^2})/3).$$

The former value is positive if and only if $t < (51 - \sqrt{1887})/51$ and the latter one is positive if and only if $t < (21 - \sqrt{231})/27$. Therefore, if $t < (51 - \sqrt{1887})/51$, $SW_d - SW_n$ in (19) is positive for any e, and, if $t > (21 - \sqrt{231})/27$, $SW_d - SW_n$ in (19) is negative for any e. $SW_d - SW_n$ in (19) is equal to zero if and only if e is equal to $\bar{e}$ in (20). Therefore, proposition 4 holds. Q.E.D.

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Location / Cost	MC at A	MC at B
Locating at A	c	$c+t$
Locating at B	$c+t$	c

(Non disclosure)

Location / Cost	MC at A	MC at B
Locating at A	$c-f$	$c+t$
Locating at B	$c+t-e$	c

(Disclosure)

MC: the constant marginal cost

Table 1: The cost structures.

Location / Cost	MC at A	MC at B
Locating at A	0	t
Locating at B	t	0

(Non disclosure)

Location / Cost	MC at A	MC at B
Locating at A	0	t
Locating at B	$t-e$	0

(Disclosure)

MC: the constant marginal cost

Table 2: The cost structures (simplified)

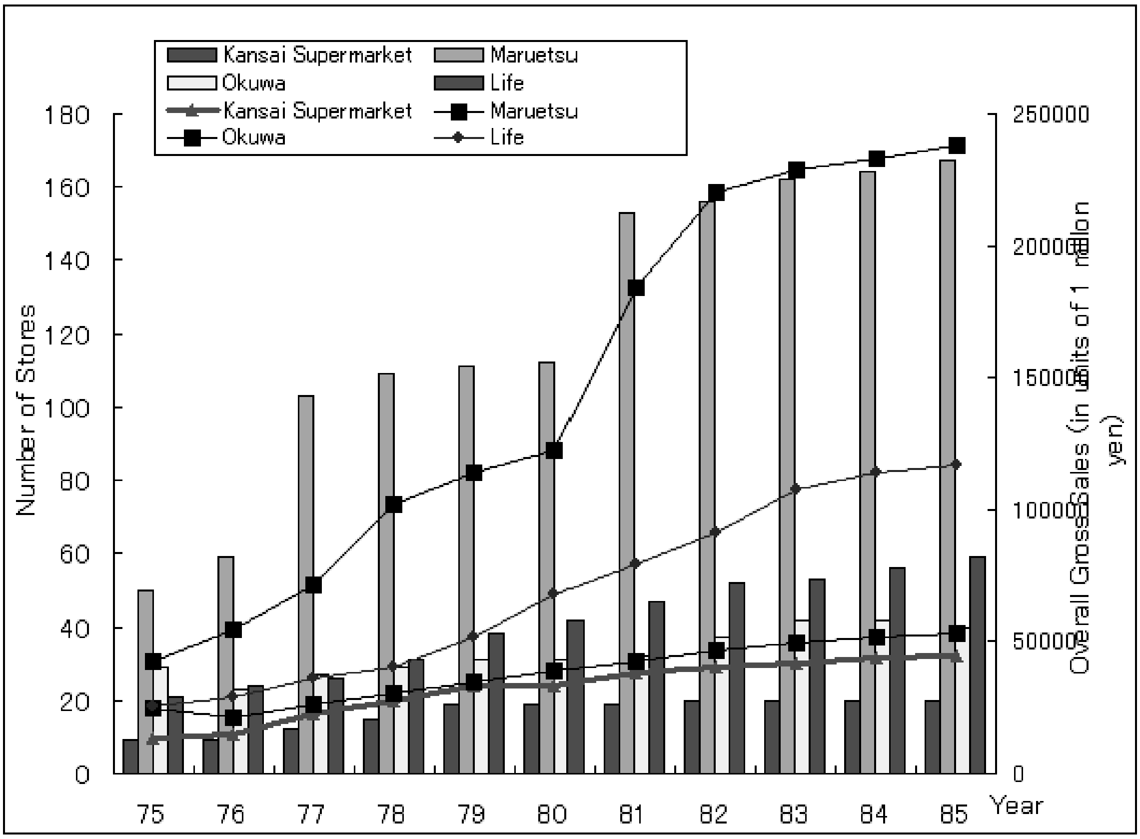


Figure 1: Number of Stores and Fluctuation in Overall Gross Sales between 1975 and 1985

Note 1: The authors referred to Guide to Distribution Economics, 1975-1987 Issue (Nihon Keizai Shimbun, Inc.) in producing this graph.

Note 2: The bar graph shows the number of stores. The sequential line graph shows overall gross sales.

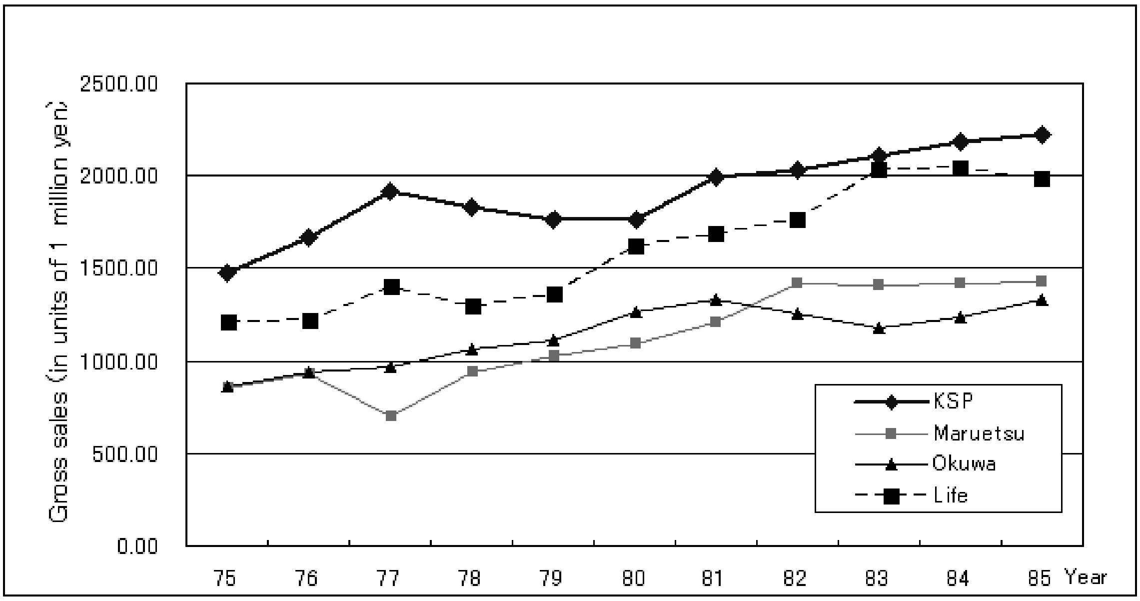
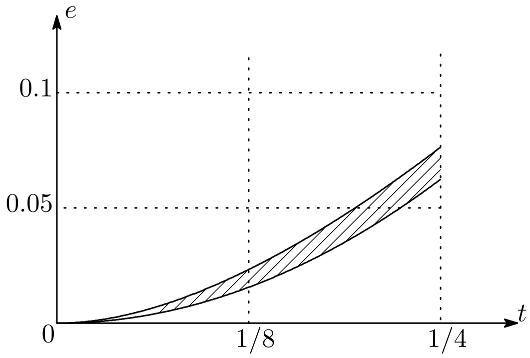


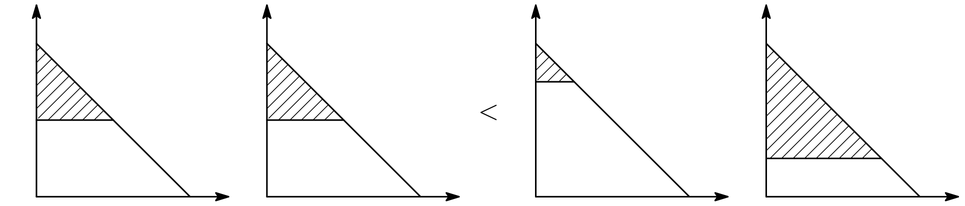
Figure 2: Fluctuation in Gross Sales per Store between 1975 and 1985

The authors referred to Guide to Distribution Economics, 1975-1987 Issue (Nihon Keizai Shimbun, Inc.) in producing this graph.



$((t, e)$ in the shaded area satisfies the inequalities in (16))

Figure 3: Profit enhancing freely disclosure



(the equal allocation) (an asymmetric allocation)

The consumer surplus in the right-hand side is larger than that in the left-hand side.

Figure 4: Consumer surplus

Supplementary Material

We now consider n-firm case. The procedure of the proof is similar to that of the main part. We assume that $t < 2/(n+4)$. This assumption ensures positive quantities supplied by the firms.

5.1 Non disclosure of know-how

Suppose that $n-k$ firms locate at A and k firms locate at B $(k = 0, 1, 2, n-1)$. The profit of the firm locating at A (denote it as $\pi_A(k)$) and the profit of the firm locating at B (denote it as $\pi_B(k)$) are:

$$\begin{aligned} \pi_A(k) &= \frac{(1+((n-k)\times 0+kt)-(n+1)\times 0)^2}{(n+1)^2}+\frac{(1+((n-k)t+k\times 0)-(n+1)t)^2}{(n+1)^2} \\ &= \frac{2-2t+(1+2k+2k^2)t^2}{(n+1)^2}, \qquad (24) \\ \pi_B(k) &= \frac{(1+((n-k)\times 0+kt)-(n+1)t)^2}{(n+1)^2}+\frac{(1+((n-k)t+k\times 0)-(n+1)\times 0)^2}{(n+1)^2} \\ &= \frac{2-2t+(1+2n+2n^2-2(1+2n)k+2k^2)t^2}{(n+1)^2}. \qquad (25) \end{aligned}$$

If $\pi_A(k) > \pi_B(k+1)$ and $\pi_B(k) > \pi_A(k-1)$, the location pattern in which k firms locate at B is an equilibrium outcome. We have the following lemma:

Lemma 3 *The following location pattern is a unique equilibrium outcome: $n/2$ firms (including firm 0) locate at A and $n/2$ firms locate at B. Under the location pattern, each firm's profit is:*

$$\pi_A(n/2) = \pi_B(n/2) = \frac{4-4t+(2+2n+n^2)t^2}{2(n+1)^2}. \qquad (26)$$

From (1), consumer surplus (denote it as CS_n) is:

$$CS_n = \frac{n^2(2-t)^2}{4(n+1)^2}. \qquad (27)$$

From (26) and (27), social welfare (denote it as SW_n) is:

$$SW_n = CS_n + (n/2)\pi_A(n/2) + (n/2)\pi_B(n/2) = \frac{n^2(12-12t+(5+4n+2n^2)t^2)}{4(n+1)^2}. \qquad (28)$$

5.2 Disclosure of know-how

Suppose that $n-k$ firms locate at A and k firms locate at B $(k = 0, 1, 2, n-1)$. The profit of the firm locating at A (denote it as $\pi^d_A(k)$) and the profit of the firm locating at B (denote it as $\pi^d_B(k)$) are:

$$\begin{aligned} \pi^d_A(k) &= \frac{(1+((n-k)\times 0+k(t-e))-(n+1)\times 0)^2}{(n+1)^2}+\frac{(1+((n-k)t+k\times 0)-(n+1)t)^2}{(n+1)^2} \\ &= \frac{2-2t+(1+2k+2k^2)t^2}{(n+1)^2}-\frac{ek(2+(2t-e)k)}{(n+1)^2}, \qquad (29) \\ \pi^d_B(k) &= \frac{(1+((n-k)\times 0+k(t-e))-(n+1)(t-e))^2}{(n+1)^2}+\frac{(1+((n-k)t+k\times 0)-(n+1)\times 0)^2}{(n+1)^2} \\ &= \frac{2-2t+(1+2n+2n^2-2(1+2n)k+2k^2)t^2}{(n+1)^2}+\frac{e(n+1-k)(2-(2t-e)(n+1-k))}{(n+1)^2} \qquad (30) \end{aligned}$$

If $\pi_A^d(k) > \pi_B^d(k+1)$ and $\pi_B^d(k) > \pi_A^d(k-1)$, the location pattern in which k firms locate at B is an equilibrium outcome. We have the following lemma:

Lemma 4 *Suppose that e satisfies the following inequalities:*

$$t^2 < e < \frac{1 + 2t - \sqrt{1 + 4t - 8t^2}}{2}. \tag{9}$$

The following location pattern is a unique equilibrium outcome: $n/2 - 1$ firms (including firm 0) locate at A and $n/2 + 1$ firms locate at B. Under the location pattern, each firm's profit is:

$$\pi_A^d(1 + n/2) = \frac{8 - 4(n+2)e + (n+2)^2 e^2 - 2(4 + (n+2)^2 e)t + 2(10 + 6n + n^2)t^2}{(n+1)^2}, \tag{32}$$

$$\pi_B^d(1 + n/2) = \frac{8 + 4ne + n^2 e^2 - 2(4 + n^2 e)t + 2(2 - 2n + n^2)t^2}{4(n+1)^2}. \tag{33}$$

From (1), consumer surplus (denote it as CS_d) is:

$$\begin{aligned} CS_d &= \frac{(2n - (n+2)(t-e))^2}{8(n+1)^2} + \frac{(2n - (n-2)t)^2}{8(n+1)^2} \\ &= \frac{8n^2 + 4n(n+2)e + (n+2)^2 e^2 - 2(4n^2 + (n+2)^2 e)t + 2(n^2+4)t^2}{8(n+1)^2}. \end{aligned} \tag{34}$$

From (32), (33), and (34), social welfare (denote it as SW_d) is:

$$\begin{aligned} SW_d &= CS_d + \pi_A^d(1 + n/2) + 3\pi_B^d(1 + n/2) \\ &= \frac{(n+2)(8n + 4(n+2)e + (2n^2 + n - 2)e^2)}{8(n+1)^2} \\ &\quad + \frac{(n+2)(-2(4n + (2n^2 + n - 2)e)t + 2(n+2)(2n-3)t^2)}{8(n+1)^2}. \end{aligned} \tag{35}$$

5.3 Comparison

In this subsection, we assume that e satisfies the inequalities in (9). We now discuss the difference between firm 0's profit in which it discloses its know-how and that in which it does not do. From (26) and (32), we have the difference:

$$\pi_A^d(n/2 + 1) - \pi_A(n/2) = \frac{(n+2)(8t^2 - 2(2 + (n+2)t)e + (n+2)e^2)}{4(n+1)^2}. \tag{36}$$

If this is positive, that is, $\pi_A^d(n/2+1) - \pi_A(n/2) > 0$, the disclosure of know-how is beneficial for firm 0. From (9) and (36), we have the following proposition:

Proposition 5 *Disclosing its know-how enhances the profit of firm* 0*, if and only if it sets the level of e as follows:*

$$t^2 < e < \frac{2 + (n+2)t - \sqrt{4 + 4(n+2)t + (n-6)(n+2)t^2}}{n+2}. \tag{37}$$

We now discuss the other firms' profits. In each case, each of them earns the same profit (see the discussion in the former subsections and equations in (26) and (33)). The difference between the profit in which firm 0 discloses its know-how and that in which it does not do. From (26) and (33), we have the difference:

$$\pi_B^d(n/2+1) - \pi_B(n/2) = \frac{n(ne^2 - (2nt-4)e - 8t^2)}{4(n+1)^2} < 0, \text{ for any } e \text{ in (37).} \tag{38}$$

From the inequality, we have the following proposition:

Proposition 6 *Suppose that firm* 0 *sets the level of* e *on the range in (37). Disclosing the know-how of firm* 0 *decreases the profits of the other three firms.*

The difference between the consumer surplus in which firm 0 discloses its know-how and that in which it does not do. From (27) and (34), we have the difference:

$$CS_d - CS_n = \frac{8t^2 + 2(n+2)(2n-(n+2)t)e + (n+2)^2e^2}{8(n+1)^2} > 0, \text{ for any } t < 2/(n+4). \tag{39}$$

From the inequality, we have the following proposition:

Proposition 7 *Disclosing the know-how of firm* 0 *enhances consumer surplus.*

The difference between social welfare in which firm 0 discloses its know-how and that in which it does not do. From (28) and (35), we have the difference:

$$SW_d - SW_n = \frac{(n+2)(2n^2+n-2)e^2 + 2(n+2)(2(n+2)-(2n^2+n-2)t)e - 8(2n+3)t^2}{8(n+1)^2}. \tag{40}$$

From the equation, we have the following proposition:

Proposition 8 *Suppose that firm* 0 *sets the level of* e *on the range in (37). Disclosing the know-how of firm* 0 *enhances social welfare, if and only if*

$$\begin{cases} t \in \left(0, 1 - \sqrt{\dfrac{2n^3+n^2+4}{(2n^2+n-2)(n+2)}}\right), \quad \textit{for any } e, \\[2ex] t \in \left[1 - \sqrt{\dfrac{2n^3+n^2+4}{(2n^2+n-2)(n+2)}}, \dfrac{3n+2}{2(2n+1)}\left(1 - \sqrt{\dfrac{3n^2-4}{(3n+2)(n+2)}}\right)\right), \\[2ex] \quad e \geq \dfrac{1}{2n^2+n-2}\left((2n^2+n-2)t - 2(n+2)\right. \\[2ex] \qquad \left. + \sqrt{\dfrac{(4(n+2)^3 - 4(n+2)^2(2n^2+n-2)t + (2n^2+n-2)(2n^3+5n^2+16n+20)t^2)}{(n+2)}}\right), \end{cases} \tag{41}$$

otherwise, it diminishes social welfare.

5.4 Cost structure

In the material, we consider the other setting which is variant of the basic model discussed in the main part. We now describe the setting which is different from that in the main.

Each multi-product firm supplies its products for the markets. Each of them has to locate at one of the markets. The incumbent can produce its product without costs at the market in which it locates, while it has to incur a constant marginal cost t to produce its product at the other market. Each entrant incurs a constant marginal cost $c > 0$ at the market in which it locates, while it has to incur a constant marginal cost $c + t$ to produce its product at the other market. That is, the entrants are less efficient than the incumbent.

Firm 0 has already located at A, that is, it has already allocated its resources to product A. The other firms decide where to locate. Before they choose their locations, firm 0 decides whether it discloses its know-how concerning product A. If it discloses its know-how, a firm locating at B can produce product A with a constant marginal cost $c+t-e$ (e is a positive constant) and a firm locating at A can produce product A with a constant marginal cost $c - f$ (f ($< e$) is a positive constant). That is, know-how disclosure by firm 0 reduces the marginal costs of the rivals.

The game runs as follows. In the first stage, firm 0 decides whether it discloses its know-how concerning product A. If it decides to disclose, it sets the level of e. In the second stage, given the decision of firm 0, firms 1, 2, and 3 decide where to locate. In the third stage, given the locations of the firms, each firm decides its quantities supplied at the markets.

5.5 Non disclosure of know-how

Suppose that $4 - k$ firms locate at A and k firms locate at B ($k = 0, 1, 2, 3$). The profit of the incumbent (denote it as $\pi_I(k)$), the profit of the entrant locating at A (denote it as $\pi^e_A(k)$), and the profit of the entrant locating at B (denote it as $\pi^e_B(k)$) are

$$\begin{aligned}
\pi_I(k) &= \frac{(1 + (0 + (3-k)c + k(c+t)) - (4+1) \times 0)^2}{(4+1)^2} + \frac{(1 + (t + (3-k)(c+t) + kc) - (4+1)t)^2}{(4+1)^2} \\
&= \frac{2(1+3c)^2 - 2(1+3c)t + (1+2k+2k^2)t^2}{25}, \qquad (42) \\
\pi^e_A(k) &= \frac{(1 + (0 + (3-k)c + k(c+t)) - (4+1)c)^2}{(4+1)^2} + \frac{(1 + (t + (3-k)(c+t) + kc) - (4+1)(c+t))^2}{(4+1)^2} \\
&= \frac{2(1-2c)^2 - 2(1-2c)t + (1+2k+2k^2)t^2}{25}, \qquad (43) \\
\pi^e_B(k) &= \frac{(1 + (0 + (3-k)c + k(c+t)) - (4+1)(c+t))^2}{(4+1)^2} + \frac{(1 + (t + (3-k)(c+t) + kc) - (4+1)c)^2}{(4+1)^2} \\
&= \frac{2(1-2c)^2 - 2(1-2c)t + (41-18k+2k^2)t^2}{25}. \qquad (44)
\end{aligned}$$

We have the following lemma:

Lemma 5 *The following location pattern is a unique equilibrium outcome: 2 firms (including firm 0) locate at A and 2 firms locate at B. Under the location pattern, each firm's profit is*

$$\pi_I(k) = \frac{2(1+3c)^2 - 2(1+3c)t + 13t^2}{25}, \quad \pi^e_A(2) = \pi^e_B(2) = \frac{2(1-2c)^2 - 2(1-2c)t + 13t^2}{25}. \qquad (45)$$

Proof: If $\pi^e_B(2)-\pi^e_A(1) > 0$ and $\pi^e_A(2)-\pi^e_B(3) > 0$, Lemma 5 holds. $\pi^e_B(2)-\pi^e_A(1) = 8t^2/25 > 0$ and $\pi^e_A(2) - \pi^e_B(3) = 8t^2/25 > 0$. Therefore, Lemma 5 holds. Q.E.D.

5.6 Disclosure of know-how

Suppose that $4-k$ firms locate at A and k firms locate at B. The profit of the incumbent (denote it as $\pi_{Id}(k)$), the profit of the entrant locating at A (denote it as $\pi^e_{Ad}(k)$), and the profit of the entrant locating at B (denote it as $\pi^e_{Bd}(k)$) are

$$\begin{aligned}
\pi_{Id}(k) &= \frac{(1+(0+(3-k)(c-f)+k(c+t-e))-(4+1)\times 0)^2}{(4+1)^2} \\
&\quad + \frac{(1+(t+(3-k)(c+t)+kc)-(4+1)t)^2}{(4+1)^2} \\
&= \frac{(1+3c)^2+(1+3c-3f)^2-2(1+3c-3f)(e-f)k+(e-f)^2k^2}{25} \\
&\quad + \frac{-2(1+3c+3fk+(e-f)k^2)t+(1+2k+2k^2)t^2}{25}, \\
\pi^e_{Ad}(k) &= \frac{(1+(0+(3-k)(c-f)+k(c+t-e))-(4+1)\times 0)^2}{(4+1)^2} \\
&\quad + \frac{(1+(t+(3-k)(c+t)+kc)-(4+1)t)^2}{(4+1)^2} \\
&= \frac{2((1-2c)^2+2(1-2c)f+2f^2)-2(1-2c+2f)(e-f)k+(e-f)^2k^2}{25} \\
&\quad + \frac{-2(1-2c-2fk+(e-f)k^2)t+(1+2k+2k^2)t^2}{25}, \\
\pi^e_{Bd}(k) &= \frac{(1+(0+(3-k)(c-f)+k(c+t-e))-(4+1)(t-e))^2}{(4+1)^2} \\
&\quad + \frac{(1+(t+(3-k)(c+t)+kc)-(4+1)\times 0)^2}{(4+1)^2} \\
&= \frac{2(1-2c)^2+(5e-3f)(2-4c+5e-3f)-2(1-2c+5e-3f)(e-f)k+(e-f)^2k^2}{25} \\
&\quad + \frac{-2(1-2c+5(5e-3f)-2(5e-4f)k+(e-f)k^2)t+(41-18k+2k^2)t^2}{25}.
\end{aligned}$$

If $\pi^e_{Bd}(3) > \pi^e_{Ad}(2)$, that is,

$$\pi^e_{Bd}(3) - \pi^e_{Ad}(2) = \frac{8((1-2(c-f))e-(f(1-2(c-f))+2f+t^2))}{25} > 0,$$

all entrants locating at B do not have an incentive to move to A and then the location pattern in which 3 firms locate at B is an equilibrium outcome. We have the following lemma:

Lemma 6 *Suppose that e satisfies the following inequality:*

$$\frac{f(1-2(c-f))+2f+t^2}{1-2(c-f)} < e. \tag{46}$$

The following location pattern is the unique equilibrium outcome: firm 0 locates at A and the other 3 firms locate at B. Under the location pattern, each firm's profit is

$$\pi_{Id}(3) = \frac{2(1+3c)^2-6(1+3c)e+9e^2-2(1+3c+9e)t+25t^2}{25}, \tag{47}$$

$$\pi^e_{Bd}(3) \quad = \quad \frac{2((1-2c)^2+2(1-2c)e+2e^2)-2(1-2c+4e)t+5t^2}{25}. \tag{48}$$

5.7 Comparison

In this subsection, we assume that e satisfies the inequalities in (46). We now discuss the difference between firm 0's profit in which it discloses its know-how and that in which it does not do. From (45) and (47), we have the difference:

$$\pi_{Id}(3) - \pi_I(2) = \frac{3(4t^2 - 2(1+3c+3t)e + 3e^2)}{25}. \tag{49}$$

If this is positive, that is, $\pi_{Id}(3) - \pi_I(2) > 0$, the disclosure of know-how is beneficial for firm 0. From (46) and (49), we have the following proposition:

Proposition 9 *Disclosing its know-how enhances the profit of firm* 0*, if and only if it sets the level of* e *as follows:*

$$\underline{B} \equiv \frac{f(1-2(c-f))+2f+t^2}{1-2(c-f)} < e, \quad e < \frac{1+3c+3t-\sqrt{(1+3c)^2+6(1+3c)t-3t^2}}{3} \equiv \bar{B}. \tag{50}$$

We provide the values of $\underline{B}$ and $\bar{B}$ and the condition that e is not empty (see, Figures 1', 2', 3', and 4')

In each case, the entrants earn the same profit levels. We now calculate the difference between the profit in which firm 0 discloses its know-how and that in which it does not do. From (45) and (48), we have the difference:

$$\pi^e_{Bd}(3) - \pi^e_B(2) = \frac{4(e^2+(1-2c-2t)e-2t^2)}{25} < 0, \text{ for any } e \text{ in (50)}. \tag{51}$$

From the inequality, we have the following proposition:

Proposition 10 *Suppose that firm* 0 *sets the level of* e *on the range in (50). Disclosing the know-how of firm* 0 *decreases the profits of the other three firms.*

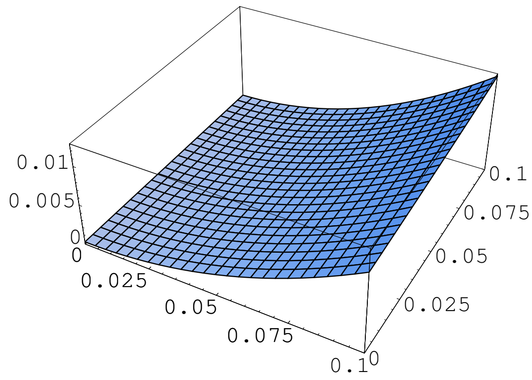


Figure 1': The lower bound ($\underline{B}$) in (50) when $f = 0$

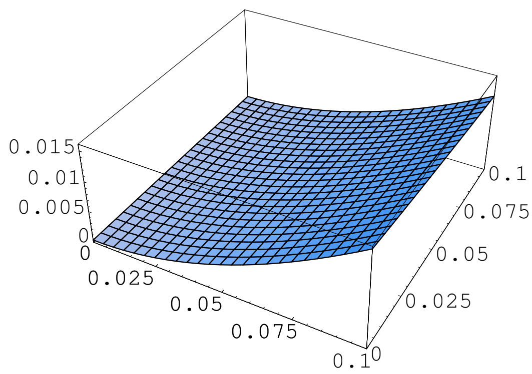


Figure 2': The upper bound ($\bar{B}$) in (50)

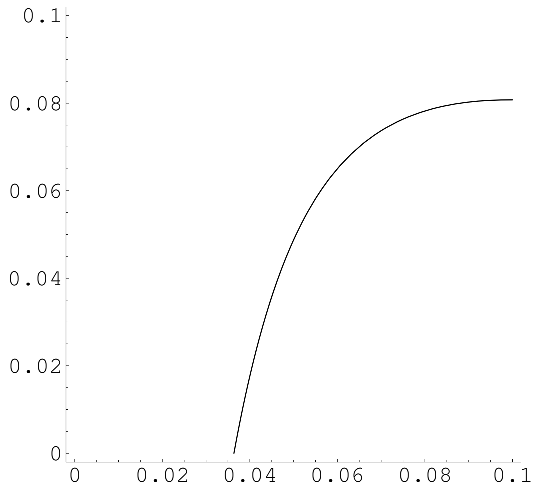


Figure 3': The condition that e is not empty when $f = 0.001$: Horizontal t, Vertical c
(The right-hand region represents the vector (t, c) which ensures the condition)

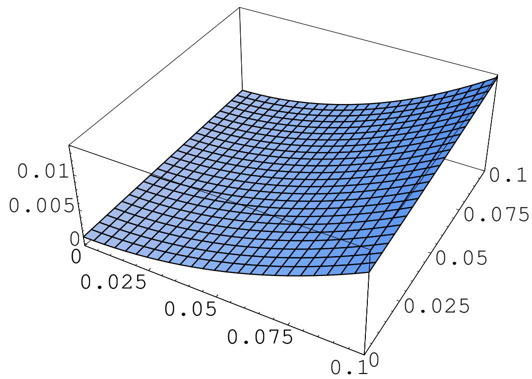


Figure 4': The lower bound ($\underline{B}$) in (50) when $f = 0.001$